Soundscapes

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LONG-TERM GOALS

To develop and validate a regional and global nowcast capability for ocean noise. The ambient noise field is, of course, a key part of the marine mammal habitat, and in turn can inform regulatory decisions by conservationists.

OBJECTIVES

Eventually this system will be coupled to global oceanographic models to provide hindcasts, nowcasts, and forecasts of the time-evolving soundscape. In terms of the types of sound sources, we will focus initially on commercial shipping and seismic exploration. As the research evolves we will gradually expand the capability to include many other types of sources.

APPROACH

The research has two principle thrusts: 1) the modeling of the soundscape, and 2) verification using datasets that have been collected around the Pacific and Atlantic Ocean basin. In terms of the modeling, we have begun with adiabatic normal modes (KRAKEN3D); in the adiabatic approximation, one assumes that the sound energy in any particular mode stays in that mode as the sound propagates radially from the source. This particular approach is extremely efficient. Longer term we will be including other models such as BELLHOP3D that can include mode coupling and 3D refractive effects.

Regardless of the model type, we first pre-calculate the transmission loss (TL) for a grid of hypothetical sources covering the globe. We then compute the noise level (NL) by convolving this TL data with a source level (SL) density. This two stage approach allows us to rapidly produce updated soundscapes as the SL density changes due to different source types or to temporal variations.

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WORK COMPLETED

In last year's report we were able to present the first, preliminary *global* soundscape due to merchant shipping and presented on a 1-degree latitude/longitude grid spacing. As background we show in figures 1-3 the bathymetry, the ensonifying field (or source level density) due to the merchant shipping, and the latest results showing the resulting soundscape. The latter represents the noise field induced by the shipping.

As discussed previously, this sort of calculation involves quite a few steps, particularly when we include different sources such as multiple ship-types, air-gun arrays, pile drivers, and sonar. As a means of ensuring the calculations are correct, we have re-structured the algorithms so that all source types are first mapped into a SL density. This SL density represents the power spectral density in a 1-Hz band for a nominal 1-m source depth and per unit area (dB/Hz/m^2). These SL density maps are very informative in themselves to get a general sense of the energy the source is putting into the water column. As mentioned above, the final stage is then to convolve that SL distribution with the channel response to bring in the propagation effects.

This year we have continued to refine and check the algorithms, and the figures presented here are the result of new calculations. While there is a lot of work in that process and it is critical to providing reliable predictions, it does not lend itself to headlines. However, we mention one specific effort to check the results. The original implementation treated the noise sources in a manner akin to overhead lighting in a room: the field was radiated out from each noise source and then summed into the global soundscape. This year we took advantage of *reciprocity* and we ran acoustic models out from every receiver location to sum up what each receiver heard from a fan of radials. We anticipated that this latter approach would be faster; however, at this point we have not reached a conclusion about which way is better. Nevertheless, the cross-check was very valuable.

Another effort this year has been to include the noise due to wind. Wind and shipping are complementary in that shipping tends to dominate the noise field below frequencies of a few hundred Hz while wind tends to dominate above that. These are two key components of the world's soundscape.

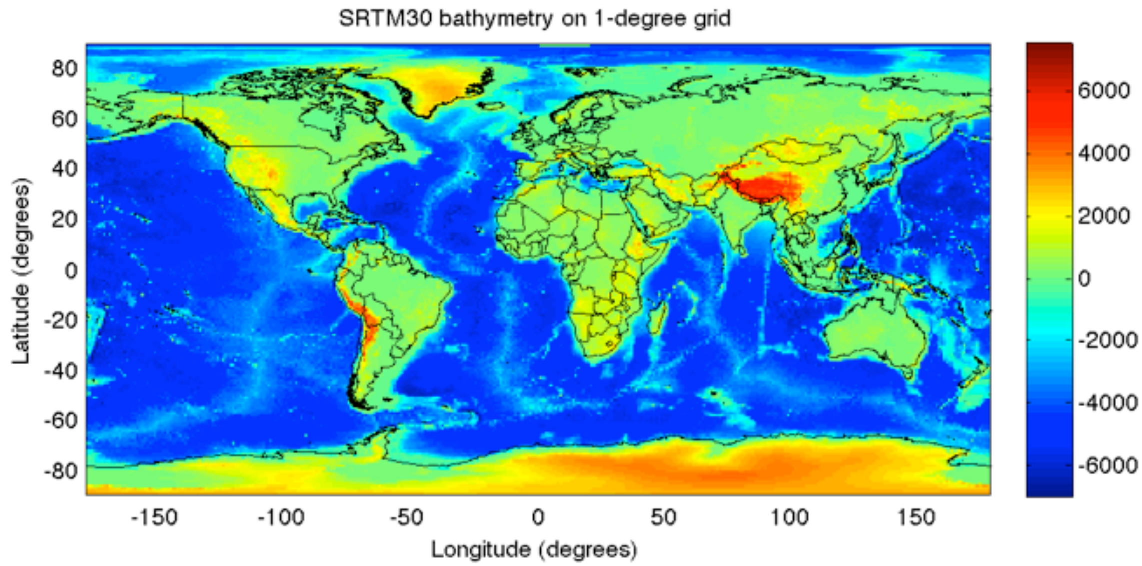

Figure 1. SRTM-30 bathymetry, here shown on an approximately 100x100 km grid.

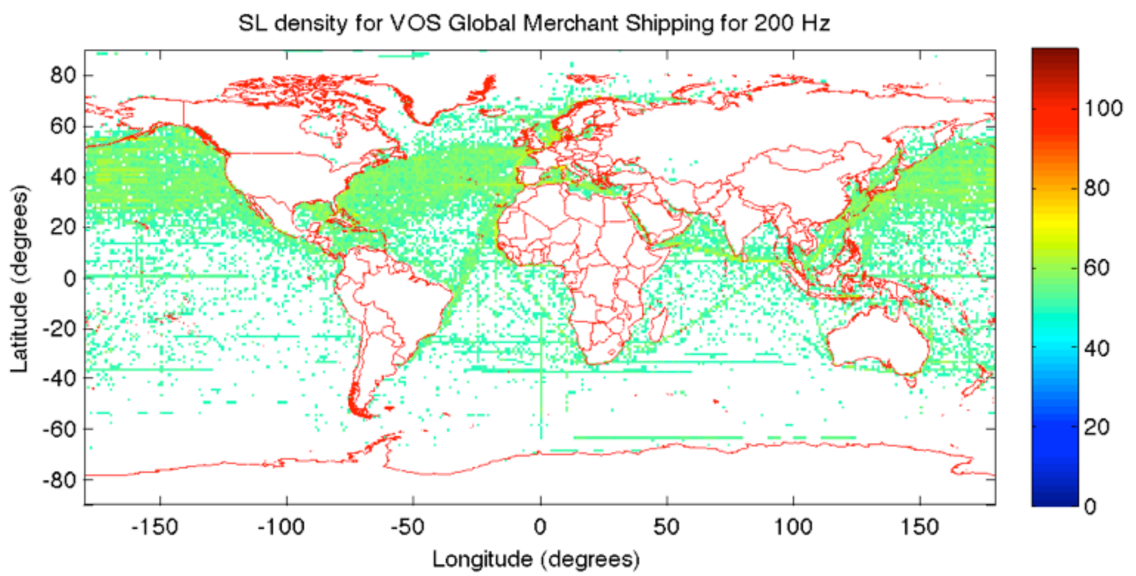

Figure 2. Source level density (dB re (1 microPascal)^2 / Hz @ 1 m/m^2)) at 200 Hz due to merchant shipping for the year 2004.

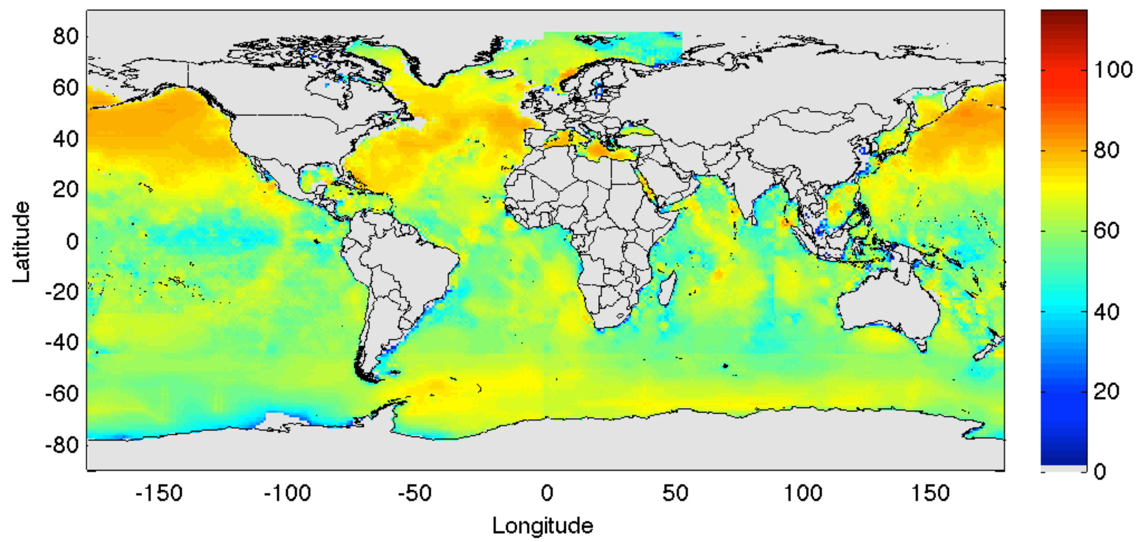

Figure 3. *Modeled noise spectrum level at 200 Hz and 200 m depth due to merchant shipping for the year 2004.*

RESULTS

The general process for calculating the noise field due to wind is the the same as that for shipping. We need environmental data needed for the entire globe. For the ocean sound speed, we used the World Ocean Atlas (WOA) annual average, already on a 1-degree grid. For bathymetry, we converted the SRTM-30 bathymetry (http://topex.ucsd.edu/WWW_html/srtm30_plus.html) to a 1-degree lat/lon grid. For bottom properties, we combined the NOAA sediment thickness database, the unclassified version of the Navy's BST (Bottom Sediment Type), and dbSeabed instaar.colorado.edu/~jenkinsc/dbseabed/).

The next key ingredient is the source level data. This turned out to be one of the biggest problems, not so much because the data were not available, but rather because almost every investigator seemed to come up with their own way of characterizing the source strength. Amongst the choices we found were monopole strengths (but with different researchers standardizing on different source depths for the monopoles); a dipole source strength; a "vertical source level"; a level based on the far-field level for a source in a half-space. A JASA (1990) paper by Kewley, et al., was very helpful in sorting this out. We implemented SL density models for the winds based on separate work by Kewley; Wilson; the Ocean and Atmospheric Master Library; and the Generic Sonar Model.

We considered two different ways to present global wind soundscapes using: 1) climatologies of wind, i.e. the historical average wind speed as a function of latitude and longitude, 2) a nominal wind speed that is uniform over the earth. Eventually we will do both; however, we chose to start with the latter uniform wind speed. This provides a sort of generalization of the Wenz curves that allows a researcher to take the local wind speed

for his or her area of interest and get an estimate of the noise level for that particular geographical area.

We did these calculations for the entire globe and for frequencies of 50, 100, 200, 400, and 800 Hz; for receiver depths of 5, 15, 30, 200, 500, and 1000 m; and for wind speeds of 10, 25, and 40 knots. Results at one wind speed can be estimated from those at another by simply shifting the levels up in proportion to the change in the source level. However, the surface roughness also increases with increasing wind speed so there are some propagation effects as well. An example slice of the resulting database is shown in Fig. 4 for a 10 knot wind; a receiver at 200 m depth; and a frequency of 100 Hz.

In a sense, these plots are easier to interpret than the shipping noise soundscapes since the source level density (the overhead 'lighting' or ensonification in the ocean) is uniform for our wind speed model. Thus the variations in level that result are strictly a function of the propagation conditions. That in turn depends on the bottom type and, to a lesser degree here, the oceanography. These effects are seen in the figure and there are some obvious features such as the mid-Atlantic ridge. One may compare these plots to those of the shipping alone to gauge the role of the variation in shipping density. However, one should consider that the wind noise is closer to the surface and this produces a dipole pattern with more energy propagating vertically.

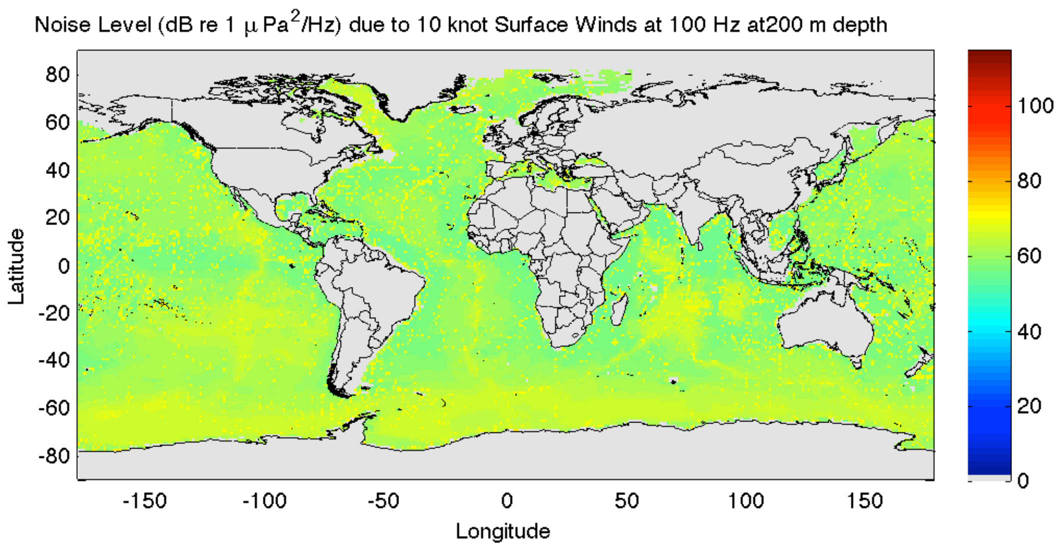

Figure 4. Modeled noise spectrum level at 100 Hz and 200 m depth due to a uniform wind field at 10 knots.

IMPACT/APPLICATIONS

The importance of this work is that it provides information on the ambient noise field, which is a key part of the marine mammal habitat, and in turn can inform regulatory decisions by conservationists. For instance, one may assess the value of ship quieting and the role of acidification. In addition, the ambient noise provides the background field against which new sound sources such as pile drivers are heard. It also facilitates the studies of masking effects on marine mammals.

RELATED PROJECTS

We have entered into a contract with the Comprehensive Test Ban Treaty Organization that provides us access to their network of hydrophones. We are also working on an Workshop on global soundscape modeling that is supported by the International Whaling Commission and the Scientific Committee on Oceanic Research. The technique permitting us to model steep angle paths in a normal mode framework was developed with the support of the ONR Ocean Acoustics program. Lastly, we are partnering with the NATO Centre for Maritime Exploration in REP-14 which will provide extensive ship noise data.

PUBLICATIONS

Michael B. Porter and Laurel J. Henderson, "Global Ocean Soundscapes", *Proceedings of the International Congress on Acoustics* 2013, Vol. 19, 010050 (Proceedings of Meetings on Acoustics), Montreal, Canada (2013) [published].

J. Gedamke, et al., "Predicting Anthropogenic Noise Contributions to U.S. Waters in The Effects of Noise on Aquatic Life," Eds. A. Popper and A. Hawkins (Conference Proceedings), 2013 [published].